The Energy-Water Nexus

Moderated by:

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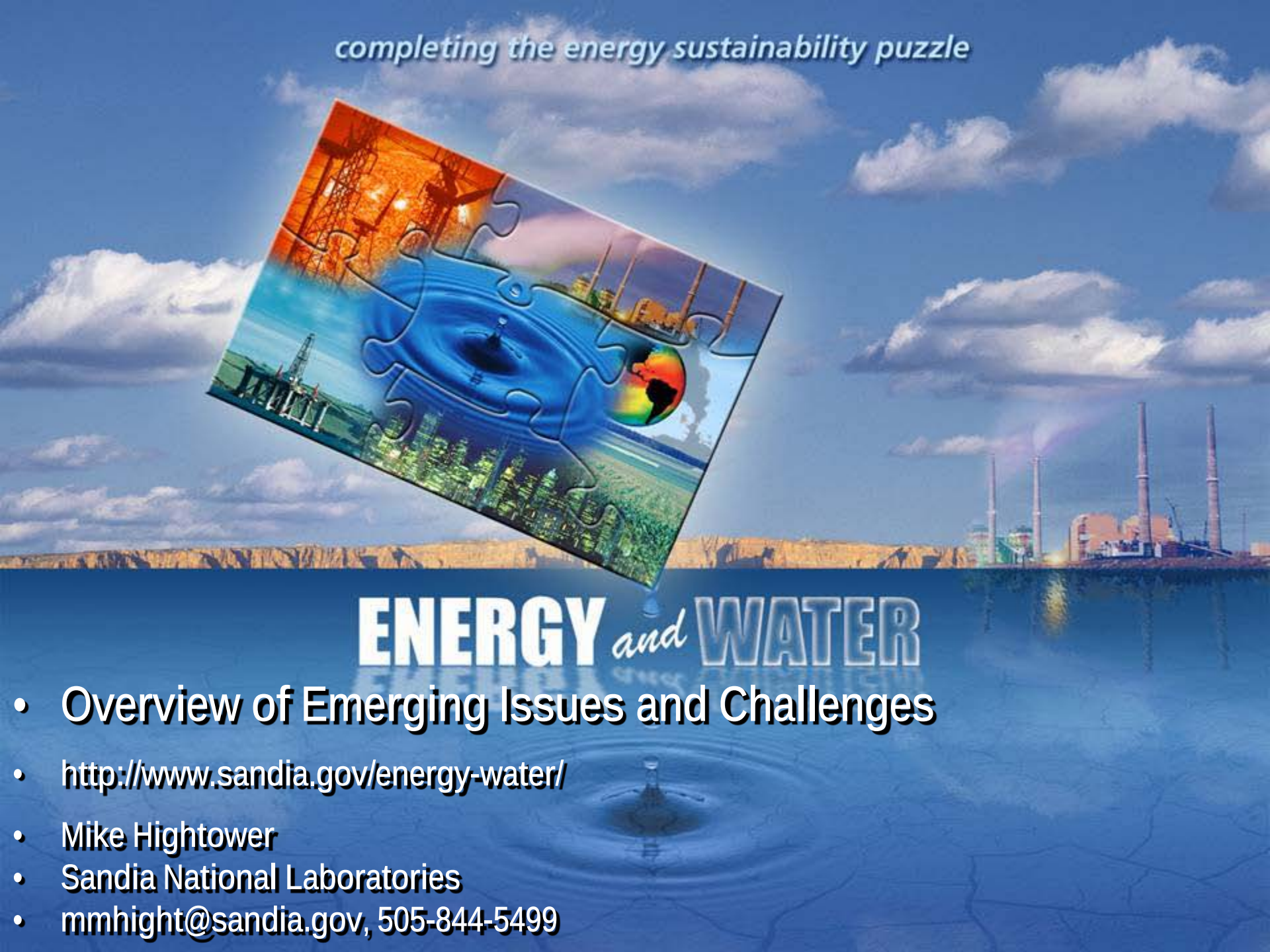
Framing the Nexus

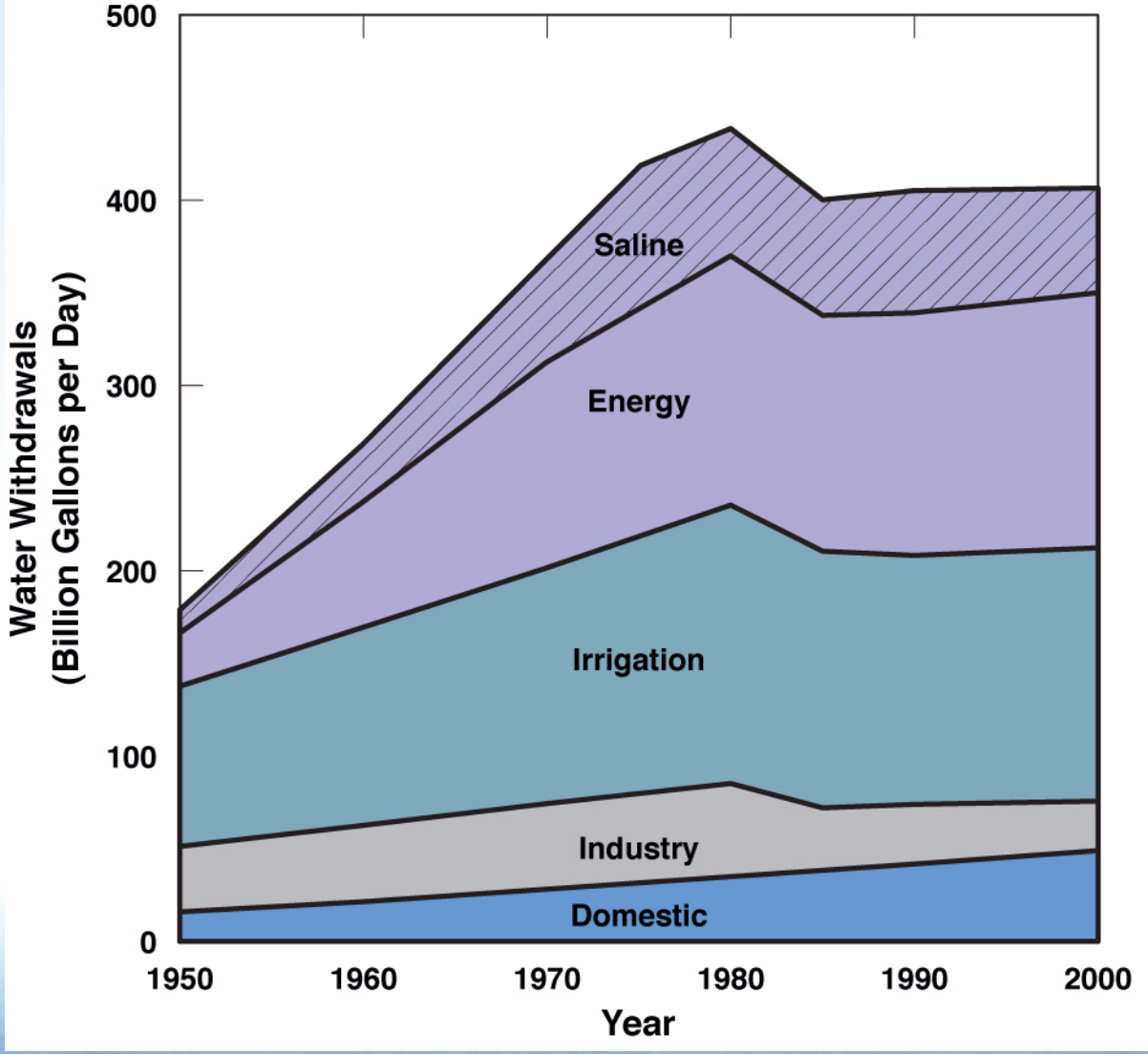
1. **Water for Energy:**
   - How much US water consumption is for electricity and fuel production?
   - Which processes are large consumers and why?
   - What reductions are possible?
2. **Energy for Water:**
   - How much US electricity and fuel consumption is for water processing?
   - Which processes are large consumers and why?
   - What reductions are possible?
3. **What opportunities exist for ARPA-E-scale funding** to significantly improve upon these processes?



- Overview of Emerging Issues and Challenges
- http://www.sandia.gov/energy-water/

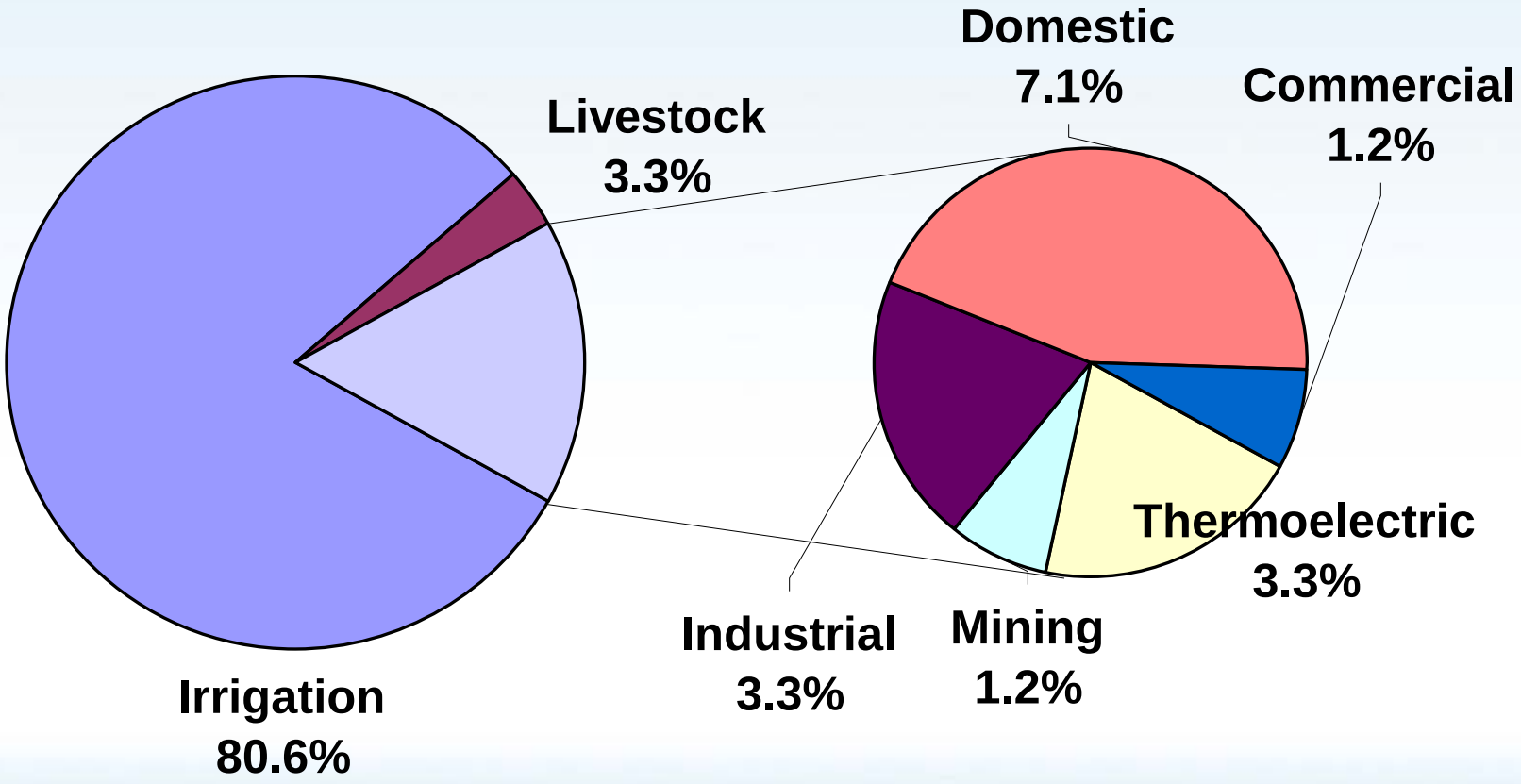
- Mike Hightower
- Sandia National Laboratories
- mmhight@sandia.gov, 505-844-5499

U.S. Fresh Water Withdrawal Trends



U.S. Fresh Water Consumption

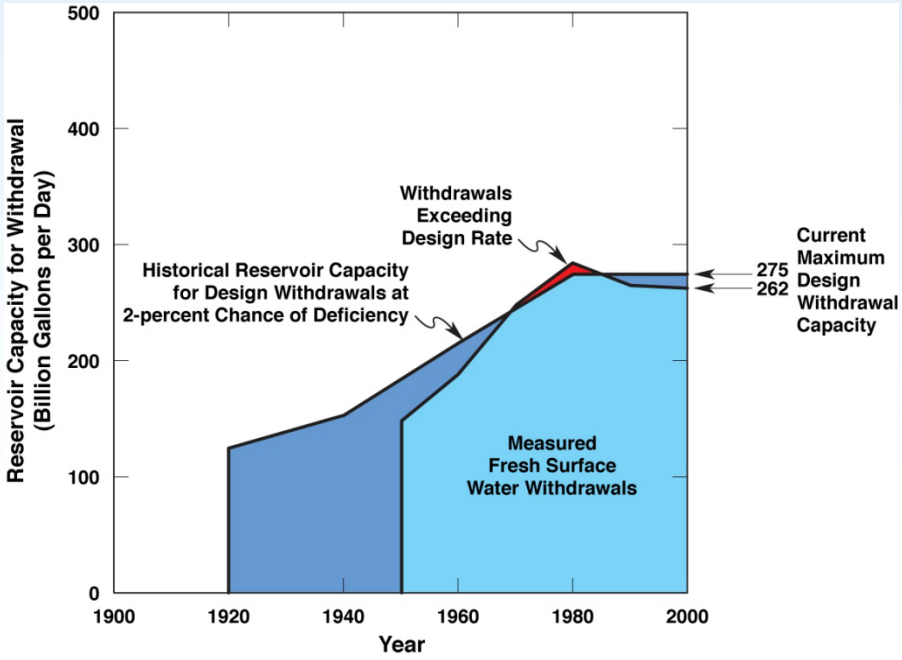
Total: 100 Bgal/day



[USGS, 1998]

Energy accounts for 27 percent of non-agricultural fresh water consumption

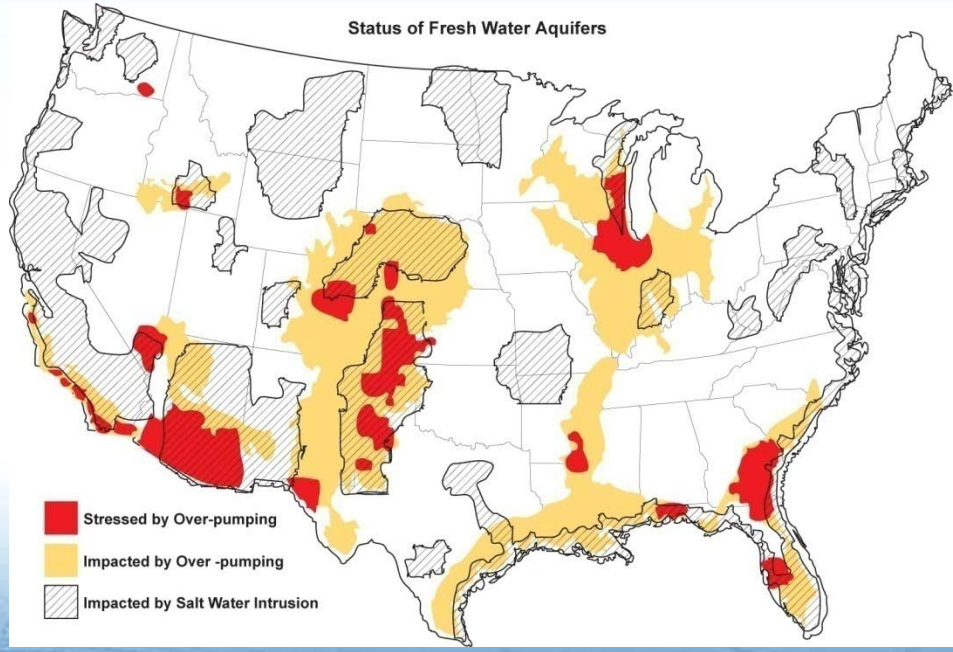
Growing Limitations on Fresh Surface and Ground Water Availability



(Based on USGS WSP-2250 1984 and Alley 2007)

- Many major ground water aquifers seeing reductions in water quality and yield

- Little increase in surface water storage capacity since 1980
- Concerns over climate impacts on surface water supplies



(Shannon 2007)

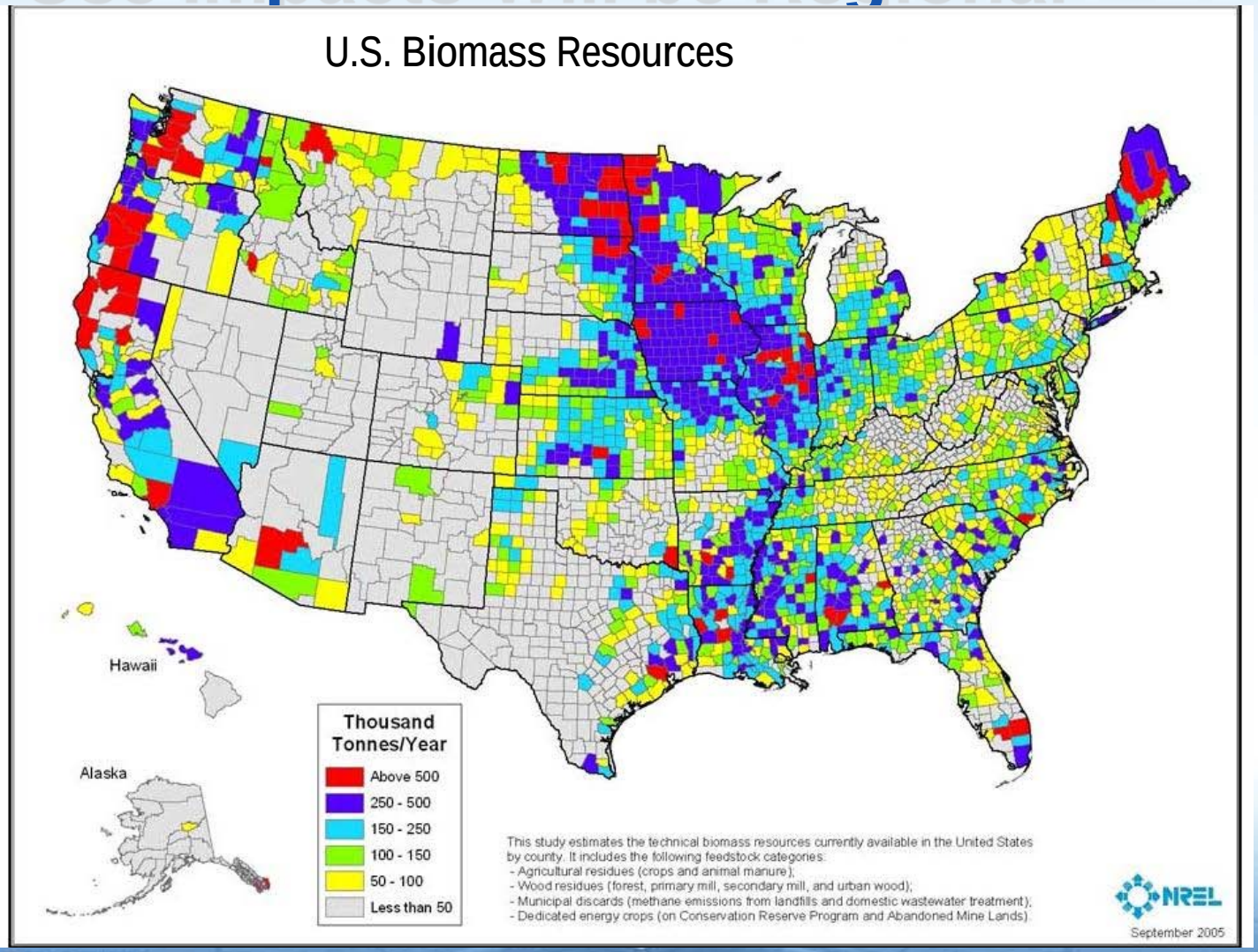
Water Consumption for Electricity

Plant Type	Cooling Process	Water Consumption (gal/MWh$_e$)
Fossil/ biomass steam turbine	Open-loop	~200-300
	Closed-loop	300-480
Natural Gas Combined-Cycle	Open-loop	100
	Closed-loop	180
	Dry	0
Concentrating Solar Thermal	Closed-loop	740-890
Carbon sequestration for fossil energy generation	~40-80% increase in water consumption	

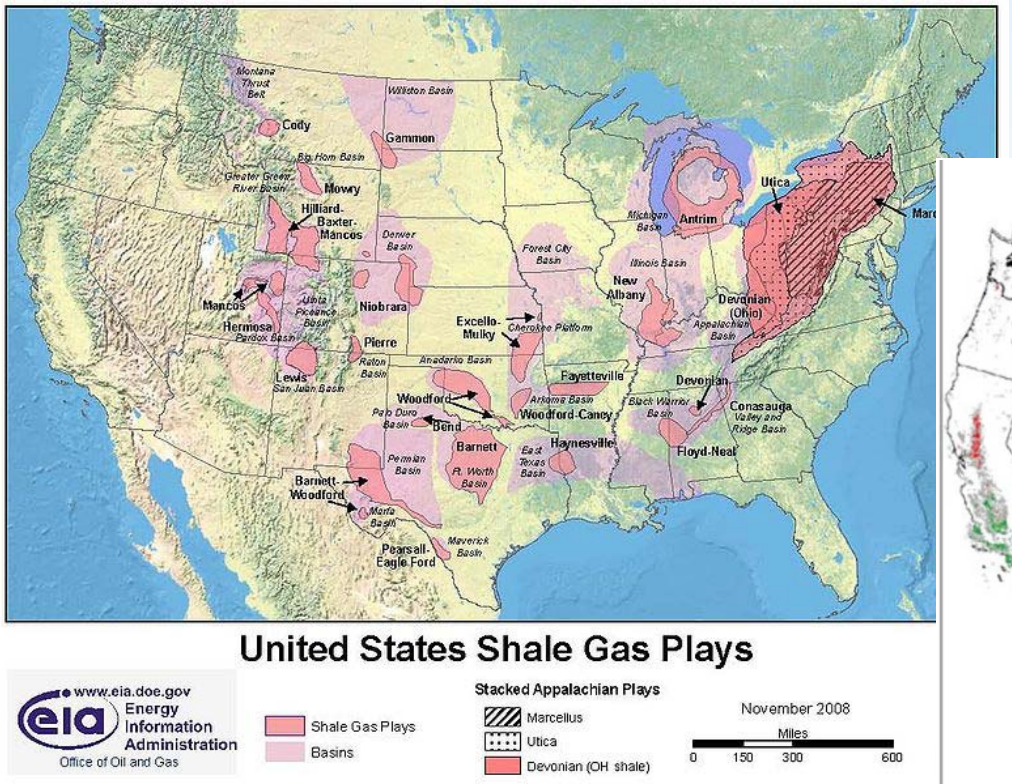
Water Consumption for Fuel

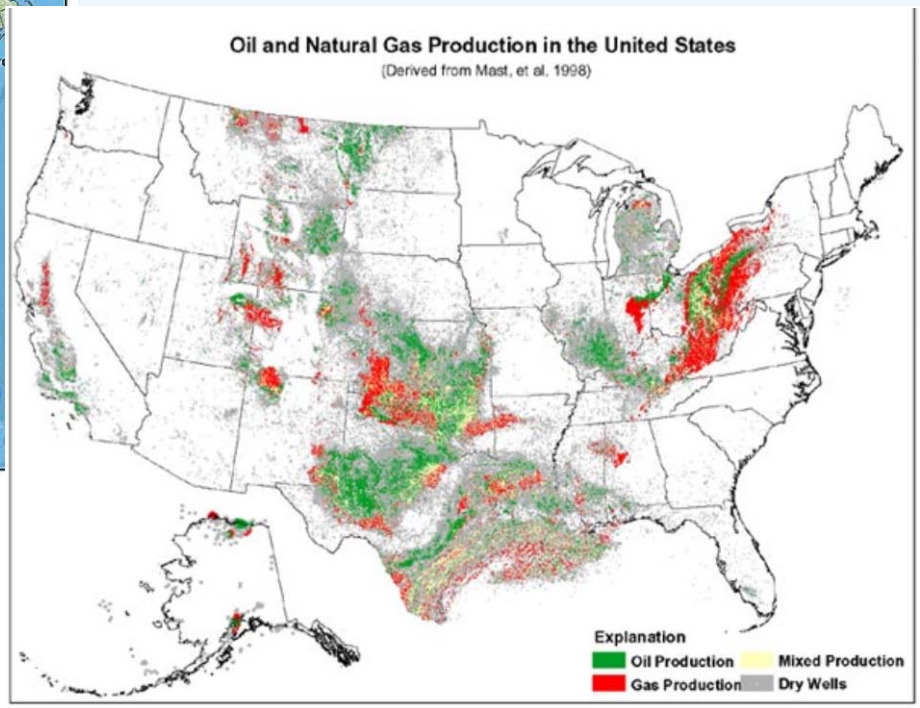
Fuel Type	Water Consumption (gal/MMBTU)
Oil Refining	7-20
Natural Gas Extraction/processing	2-3
Grain Ethanol Processing	12-160
Corn Irrigation for Ethanol	2500-31600
Oil Sands	20-50

Alternative Transportation Fuel Water Use Impacts Will be Regional



Energy Development Produced Water Quality and Use Challenges and Options



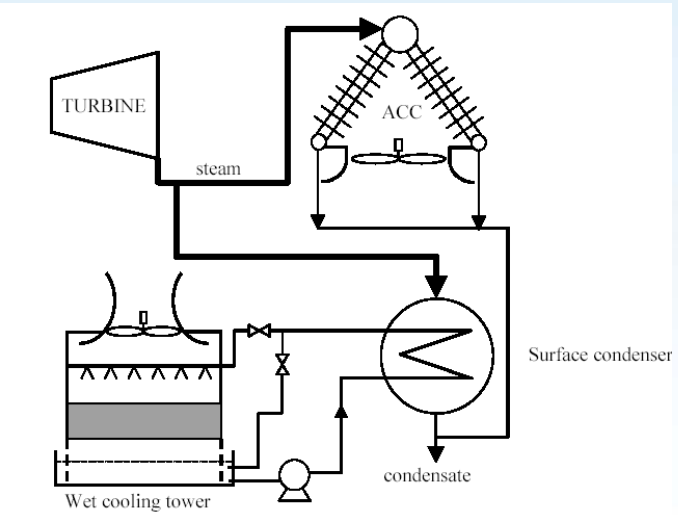


Gas Shale Development

- ~3-5 Mgal consumed water per hydrofractured well
- Regional water limitations will occur

Oil and Gas Produced Water

Research and Development Priorities for the Electric Power Sector



Hybrid Wet-Dry Cooling

- Improve dry and hybrid cooling system performance and cost
- Improve ecological performance of intake structures for hydro, once-through, and ocean cooling
- Improve materials and cooling approaches compatible with use of degraded water
- Electric grid infrastructure upgrades to improve low water use distributed technology integration

Research and Development Priorities for Alternative Fuels Sector

- Reduce water use for cooling in biofuels and alternative fuels production
- Reduce water use in processing
- Develop low fresh water use technologies such as algal biodiesel, drought tolerant crops
- Assess non-traditional water use for fuels applications
- Assess hydrologic impacts of large cellulose biofuels scale-up, oil shale, oil sands, etc.

Advanced Research Projects Agency • ENERGY

U.S. DEPARTMENT OF ENERGY

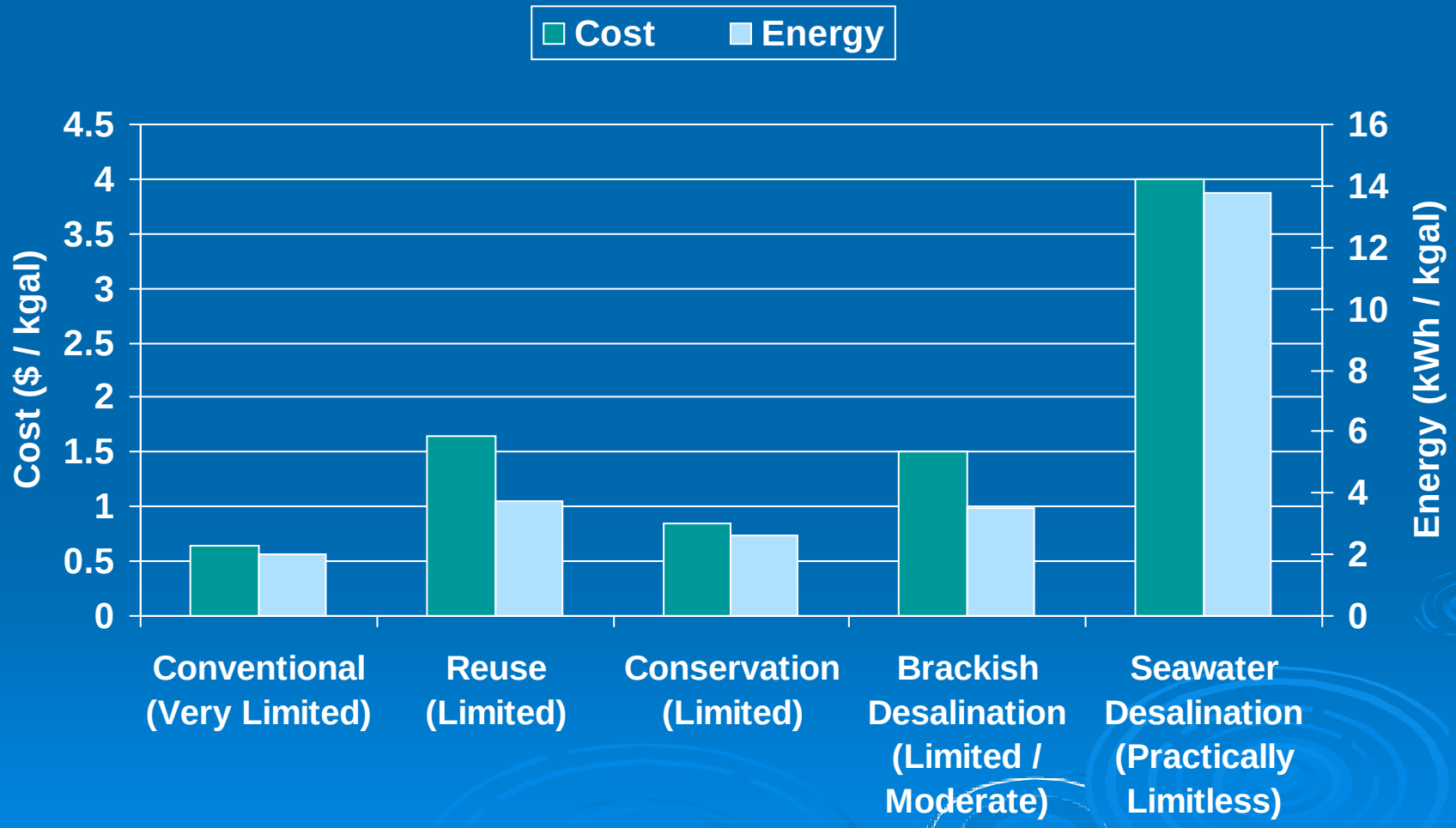
Nikolay Voutchkov, PE, BCEE
Water Globe Consulting

Research Program Framework for Advanced Low-Energy Water Technologies

Where We Are and Where We Want to be in Non-Traditional Water Production Technologies?

Parameter	Today	Within 5 Years	Within 20 Years
Cost of Water (2010 US$/kgal)	US$2.0-3.0	US$1.5-2.5	US$1.0-1.5
Construction Cost (Million US$/MGD)	4.5-8.0	4.0-6.5	2.0-3.5
Power Use of SWRO System (kWh/kgal)	9.5-10.5	8.0-10.0	5.0-6.5
Membrane Productivity (gallons/day/membrane)	6,500-12,500	9,000-15,000	25,000-40,000
Membrane Useful Life (years)	5-7	7-10	10-15
Plant Recovery Ratio (%)	45-50	50-55	55-65

US Water Supply Sources



Sustainability of Water Supply Alternatives

Water Technology	Percent of Total Water Production Costs Contributed to	
	Energy	Chemicals
Conventional Water Treatment	15	70
Wastewater Treatment & Reclamation	30	60
Desalination	35	5

Innovative Technologies Should Focus on Disruptive Reduction of:

- Chemical Use for Conventional W & WW Treatment & Reclamation
- Energy for Water Reclamation & Desalination

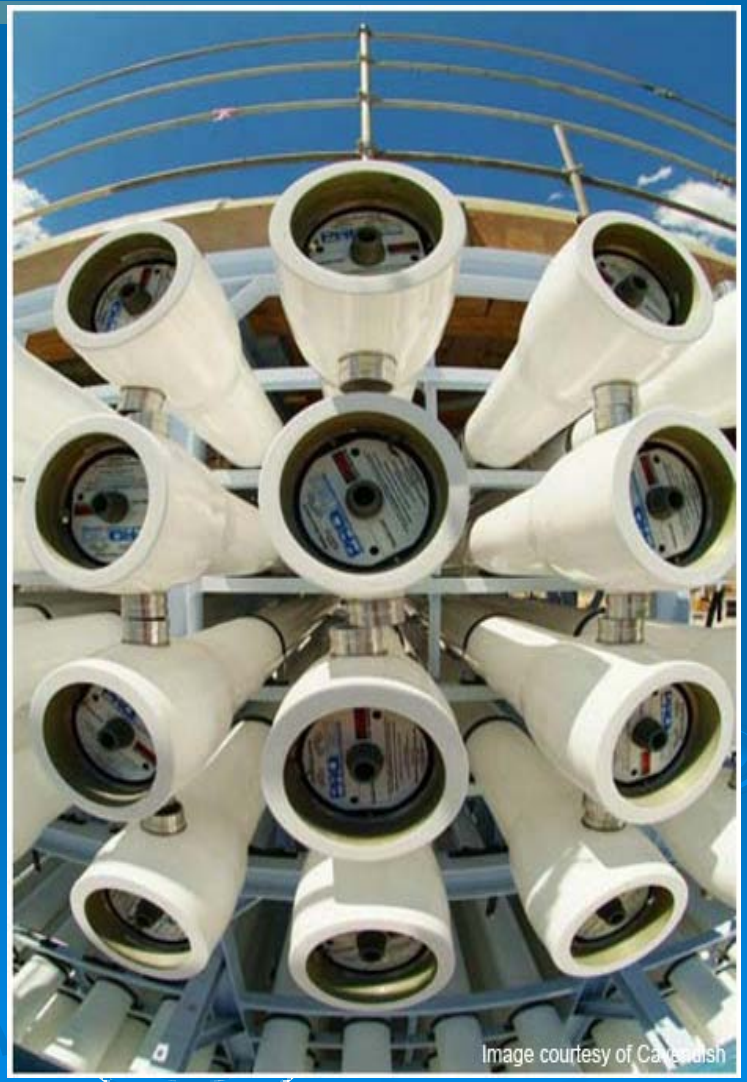
Water Reclamation & Desalination

- Focus - Technologies that Disruptively Reduce Energy & Chemical Use for:
  - **Salt and Contaminant Removal**
  - **Concentrate/Waste Management**

Prime Target: Technologies That Use Low-Energy Non-Reverse Osmosis Separation

&

Advanced Biological Removal or Destruction of Impurities



Conventional Water & Wastewater Treatment & Reclamation

- Focus - Technologies that Eliminate or Reduce Use of Chemicals for:
  - **Source Water Coagulation & Oxidation**
  - **Disinfection**
  - **Product Water Conditioning – Selective Addition or Removal of Constituents**

Prime Target: Low-Energy Technologies That Generate Treatment Chemicals from Water /WW Constituents!

Focus Area 1- Advanced Technologies for:

- Bio-membrane & Enzymatic Water Treatment
- Osmotic Water Transport & Impurity Removal
- Micro-electromagnetic Water or Impurity Separation
- Hybrid Thermal/Membrane Water Transport
- Zero-Liquid Waste Discharge
- Near-Zero Chemical Use

Focus Area 2
Symbiotic Technologies for Harnessing of Energy and Chemicals Embedded in Water

- Harnessing Energy from Water – i.e., Osmotic Power
- Harnessing Energy from Wastewater – i.e., Energy from Organic Constituents
- GHG Sequestration – i.e., Locking Carbon Dioxide, Nitrogen and Other Compounds in Water
- Harnessing Chemicals Embedded in Water for Water & Wastewater Treatment

Focus Area 3
Platform Technologies &Materials to Leverage Innovation

- Nano-Structured Membranes/Materials for:
  - Forward & Pressure Retarded Osmosis
  - Micro, Ultra & Nano-filtration
  - Wastewater Treatment, Water Production & Waste Minimization
- Advanced Membrane Bioreactor Technologies with Multifaceted Applications
  - Wastewater Treatment
  - Elimination of Chemical Use and Bio-fouling for Water Production

Key Criteria for How Valuable is Proposed Research Topic

- Disruptive Reduction of:
  - Energy;
  - Water Production Costs;
  - Carbon Footprint;

  (over 20 % Reduction of Current Status-Quo)

- High-Impact Science - Wide Range of Applications for:
  - Conventional and No-Traditional Water Source Treatment;
  - Water Reuse;
  - and Wastewater Treatment.

Questions?

Energy-Water Nexus Networking Session

Monday 8 pm (Belvedere, bar in the hotel lobby)